Introduction To The BTeV Project

S. Stone

Collaboration Spokesperson

Welcome

- We welcome you to the CD-2/3a review
- We look forward to getting the BTeV baseline established and approval of the long-lead time & time-critical purchases
- Our job is to provide you with the material to demonstrate that we have:
  - A sound technical design
  - Well understood & reliable cost estimate
  - An achievable schedule
  - A competent project management team in place

BTeV Collaboration

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Syracuse University-
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G. Bonvicini, D. Cinabro, A. Schreiner

University of Wisconsin
M. Sheaff

York University - S. Menary

Collaboration

- A large & talented group of physicists (~180 & growing) from many institutions that are dedicated & eager to do this physics
- Experienced technical staffs at Fermilab & collaborating institutions
- BTeV includes universities and national labs in the US & Puerto Rico, Italy, Russia, China, Canada & Belarus
  - There are three national labs: Frascati, IHEP/Protvino & FNAL

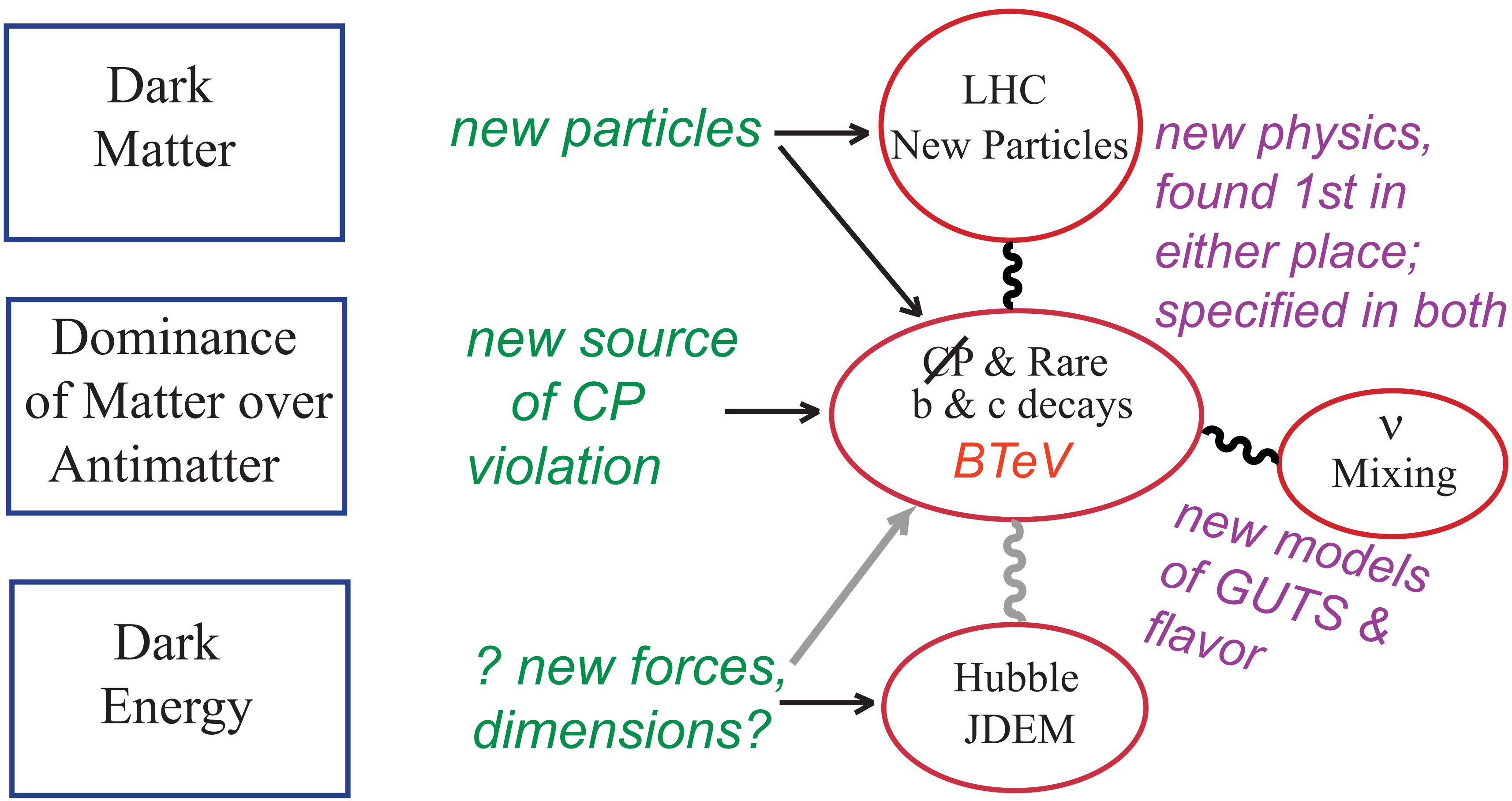
Fermilab & External Institutions

- Scientists and technical staff from these groups will help construct the BTeV detector, help commission it, operate it and extract the physics
- Managing such a diverse group requires special effort, skills, and experience. These exist within Fermilab and the collaborating institutions. Our management team meets this challenge.
- This model takes maximal advantage of resources both at universities and at large laboratories
- This requires excellent communication between the experiment spokesperson, the project management, the lab management & the DOE. We have excellent management systems in place.

The Physics: General

Mysteries

Solutions:
New Physics



BTeV Measurements on CP & Mixing

Physics Quantity	Decay Mode	Vertex Trigger	K/π sep	γ det	Decay time σ
$\sin(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\sin(2\alpha)$	$B^o \to \pi^+\pi^-$ & $B_s \to K^+K^-$	✓	✓		✓
$\cos(2\alpha)$	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	✓	✓	✓	
$\text{sign}(\sin(2\alpha))$	$B^o \to \rho\pi$ & $B^o \to \pi^+\pi^-$	✓	✓	✓	
$\sin(\gamma)$	$B_s \to D_s K^-$	✓	✓		✓
$\sin(\gamma)$	$B^o \to D^o K^-$	✓	✓		
$\sin(\gamma)$	$B \to K\pi$	✓	✓	✓	
$\sin(2\chi)$	$B_s \to J/\psi\eta'$, $J/\psi\eta$		✓	✓	✓
$\sin(2\beta)$	$B^o \to J/\psi K_s$				
$\cos(2\beta)$	$B^o \to J/\psi K^*$ & $B_s \to J/\psi\phi$		✓		
x_s	$B_s \to D_s\pi^-$	✓	✓		✓
$\Delta\Gamma$ for B_s	$B_s \to J/\psi\eta'$, K^+K^-, $D_s\pi^-$	✓	✓	✓	✓

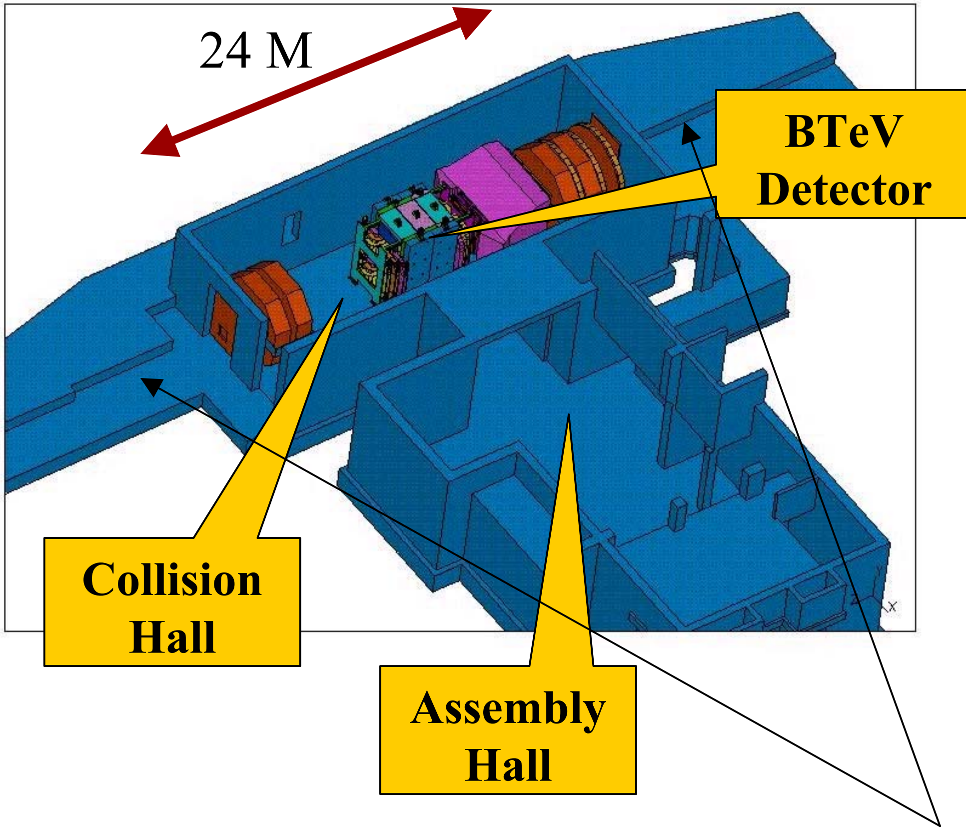
- These are some of the physics drivers that set the requirements

Some Highlights of the Physics Reach

- Best measurement of CP violating angle γ using $B_s \to D_s K^-$ ($\pm 8^o$ in 10^7 sec)
- Best measurement of CP violating angle α using $B^o \to \rho\pi \to \pi^+\pi^-\pi^o$ ($\pm 4^o$ in 10^7 sec)
- Best measurement of CP violating angle χ using $B_s \to J/\psi\eta^{(\prime)}$ ($\pm 1^o$ in 10^7 sec)
- Best measurement of B_s mixing rate
- Overall, best sensitivities of any Heavy Quark Experiment

The BTeV Project

Below Grade	Above Grade

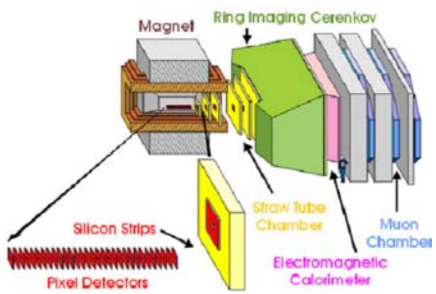


Beams do not now collide at C0. Magnets to make them collide will be built and installed. They extend about 200m on each side of the center of the Collision Hall.

Project Elements

WBS 1.0

BTeV Detector



WBS 3.0

C0 Hall Outfitting

WBS 4.0

BTeV Project

WBS 2.0

C0 Interaction Region

Requirements on C0 IR

- Peak Luminosity ~2×10^{32} cm^{-2} s^{-1} (β^*<50 cm)
- Interoperability: Must allow for operation at C0 or simultaneously at B0 & D0
- Non-interference with BTeV detector – last quadrupole closest to collision point is 5 m farther away than in CDF or D0
- Schedule: Must be ready by shutdown in middle of 2009

Requirements on C0 Outfitting *(WBS 3.0)*

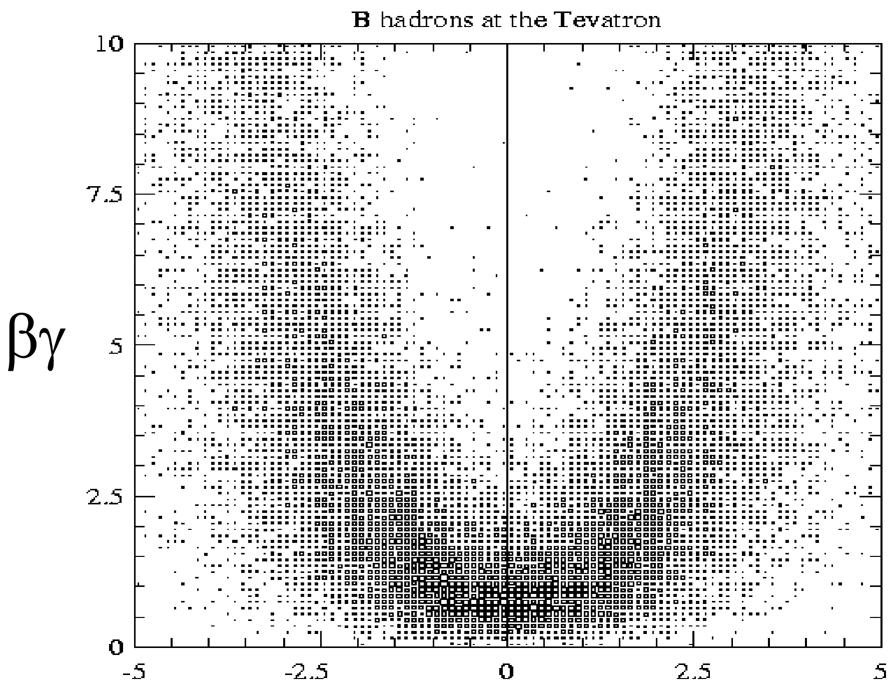
- Building already exists
- We need to
  - Provide the architectural, structural, mechanical and electrical work for the BTeV detector (WBS 1.0).
  - Provide the modifications to the C-0 Service Building and primary power for the Interaction Region (WBS 2.0).

Detector Requirements: First - Characteristics of hadronic b production

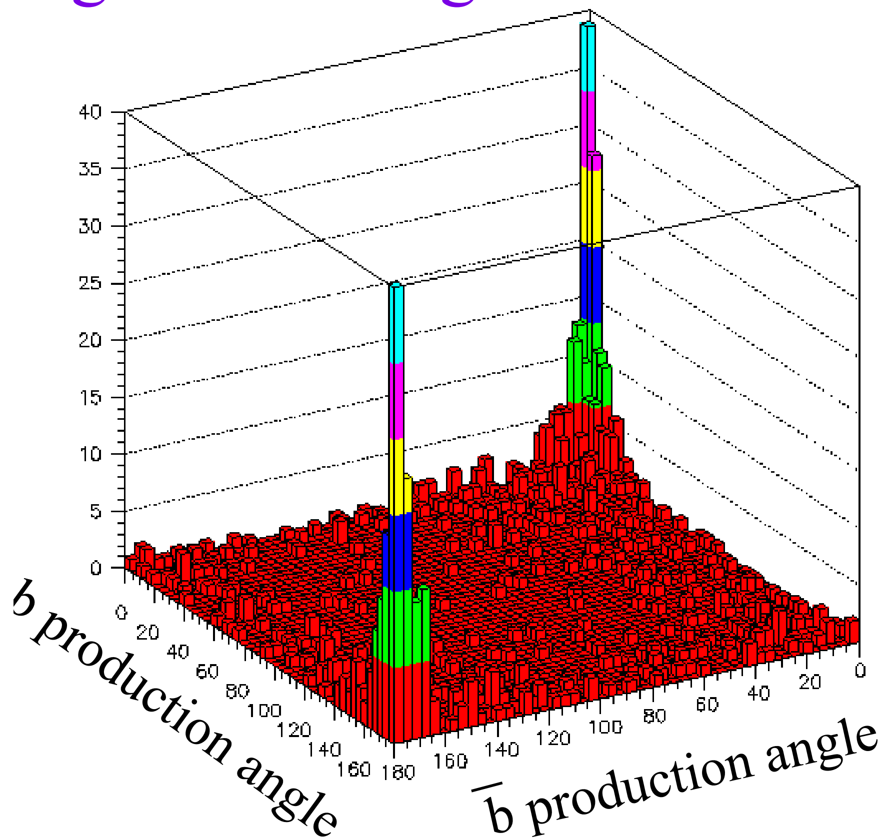
$$p\bar{p} \rightarrow b\bar{b} + X$$

The higher momentum b's are at larger η's

b production peaks at large angles with large $\bar{b}b$ correlation



$$\eta = -\ln(\tan\frac{\theta}{2})$$



Requirements: General

- Intimately tied to Physics Goals
- In general, within the acceptance of the spectrometer (10 – 300 mr with respect to beam) we need to:
  - Detect charged tracks & measure their 3-momenta
  - Measure the point of origin of the charged tracks (vertices)
  - Detect neutrals & measure their 3-momenta
  - Reveal the identity of charged tracks (e, μ, π, K, p)
  - Trigger & acquire the data (DAQ)
- Detector we designed meets the requirements

Basics Reasons for the Requirements

- B's (& D's) are long lived, ~1.5 ps, so if they are moving with reasonable velocity they go ~3 mm before they decay. This allows us to Trigger on the the presence of a B decay (*detached vertex*).
- B's are produced in pairs $p\bar{p}\rightarrow b\bar{b}+X$, and for many crucial measurements we must detect one b fully and some parts of the other: "flavor tagging"
- Physics states of great interest now are varied and contain both charged modes and neutrals, B_d & B_s

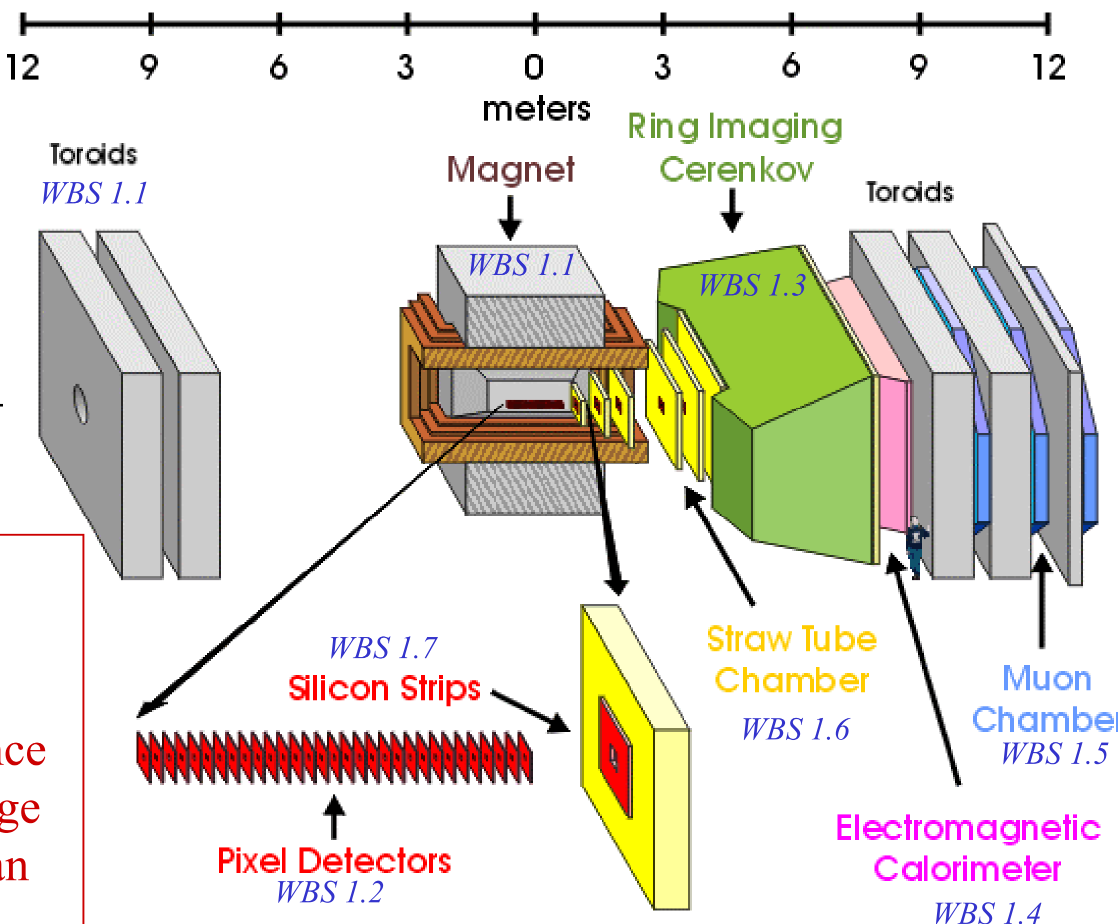
More Basic Reasons

- Many modes contain γ, π^o & η, so need excellent electromagnetic calorimetery
- B_s oscillations are fast, so need excellent time resolution ~<50 fs, compared to ~1500 fs lifetime. Also very useful to reduce backgrounds in reconstructed states
- Physics Backgrounds from $\pi \Leftrightarrow K$ can be lethal
  - $B_s \rightarrow D_s\, \pi^-$ is 15X $B_s \rightarrow D_s\, K^-$
  - $B^o \rightarrow K^* \pi \rightarrow K^{\mp}\pi^{\pm}\pi^o$ is 2X $B^o \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^o$
  - So excellent charged hadron identification is a must

The BTeV Detector

BTeV Detector Layout

beam line



$\overline{p} \rightarrow$

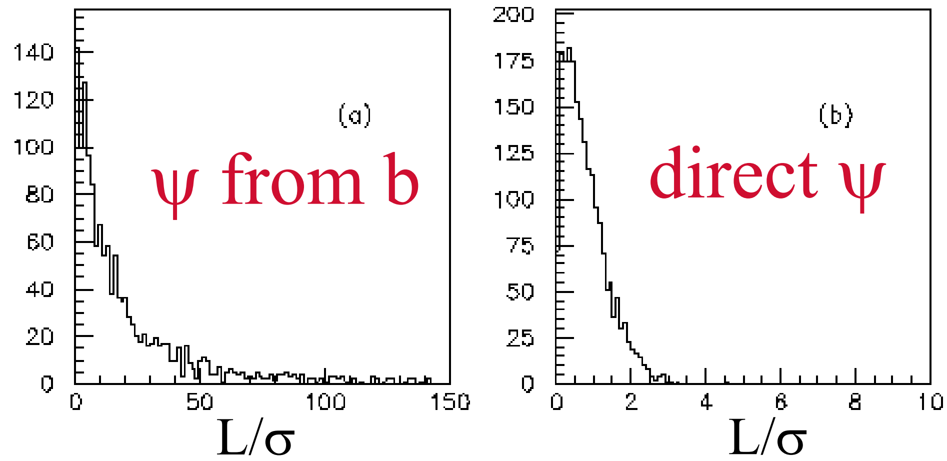
Pixel detector inside magnet, allows first level triggering, on detached vertices, since low p_t tracks with large multiple scattering can be eliminated

In addition:
Trigger-*WBS 1.8*
DAQ-*WBS 1.9*
Install & Integrate-*WBS 1.10*

Fundamentals: Decay Time Resolution

- Excellent decay time resolution
  - ➢ Reduces background
  - ➢ Allows detached vertex trigger
- The average decay distance and the uncertainty in the average decay distance are functions of B momentum:

$$\langle L \rangle = \gamma\beta c\tau_B$$
$$= 480\ \mu m \times p_B/m_B$$

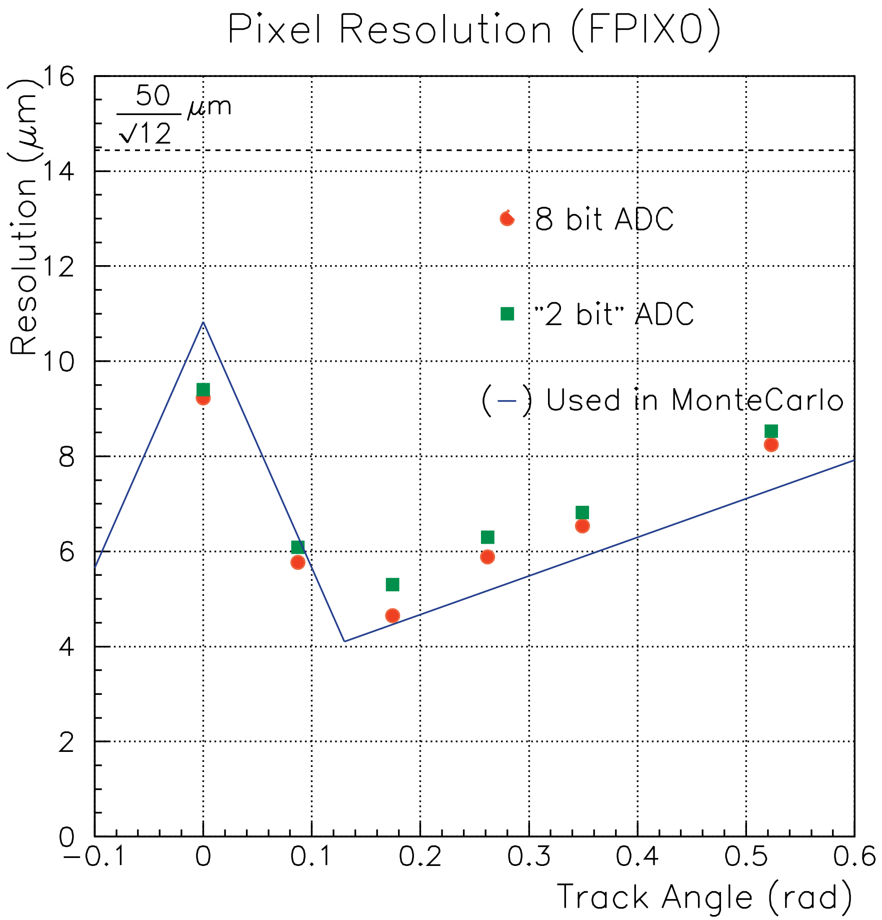


CDF/D0 region

LHC-b region

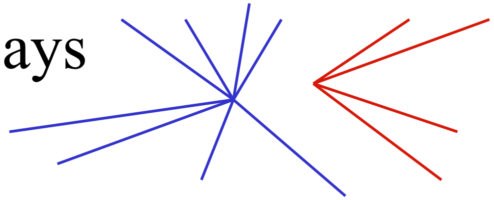
Pixels *(WBS 1.2)*

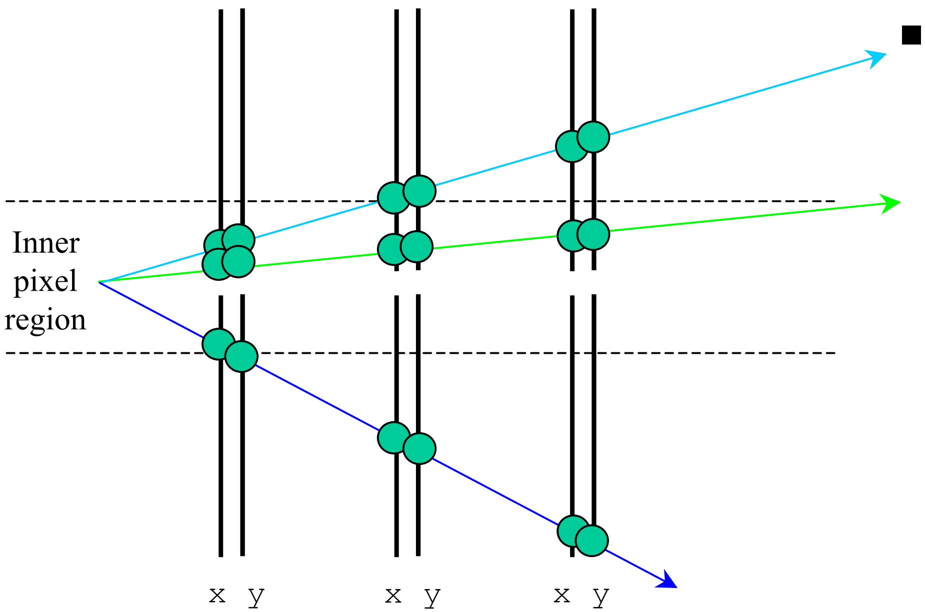
- Pixel – working systems studied in beams, including "almost" final electronics
- Full mechanical design done and being tested
- Pixels are inside of beam pipe in machine vacuum – OK with accelerator provided the outgassing rate is below specified limits (review document linked to Review web page). Current tests satisfy this requirement.



Pixel Trigger Overview *(WBS 1.8)*

◆ Idea: find primary vertices & detached tracks from b or c decays





- Pixel hits from 3 stations are sent to an FPGA tracker that matches "interior" and "exterior track hits
- Interior and exterior triplets are sent to a farm of DSPs to complete the pattern recognition:
  - interior/exterior triplet matcher
  - fake-track removal

Trigger Performance

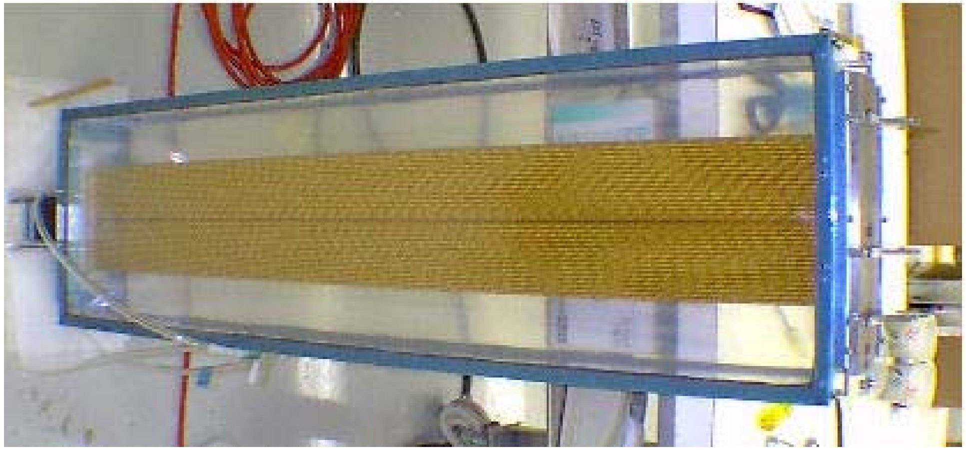
- For a requirement of at least 2 tracks detached by more than 4σ, we trigger on only 1% of the beam crossings and achieve the following efficiencies for these states at Level I:

State	efficiency(%)	state	efficiency(%)
$B \rightarrow \pi^+\pi^-$	55	$B^o \rightarrow K^+\pi^-$	54
$B_s \rightarrow D_s K$	70	$B^o \rightarrow J/\psi\ K_s$	50
$B^- \rightarrow D^o K^-$	60	$B_s \rightarrow J/\psi K^*$	69
$B^- \rightarrow K_s \pi^-$	40	$B^o \rightarrow K^*\gamma$	40

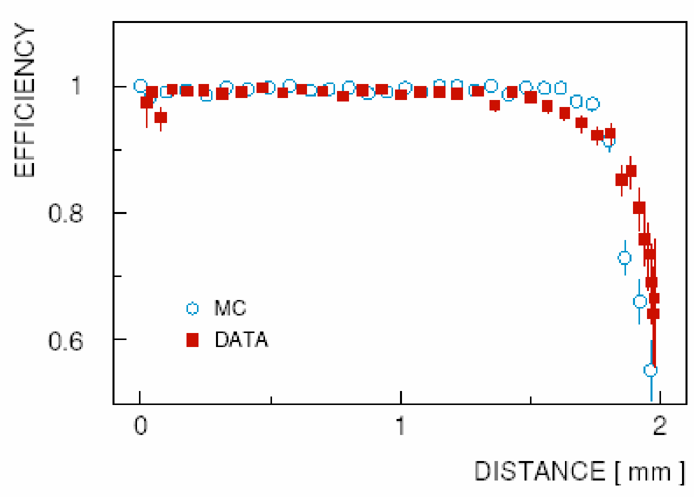
Tracking

- Straws *(WBS 1.6):*

  protoype undergoing tests, uses Atlas design as basis



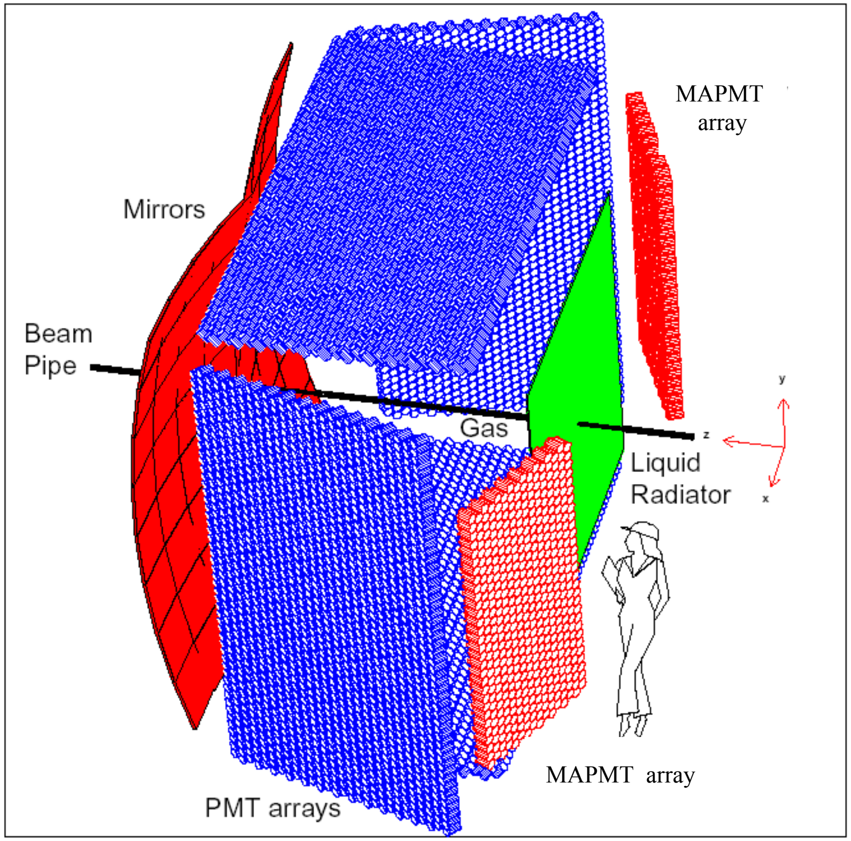
- Straw test beam using Ar(80%)/CO_2(20%)



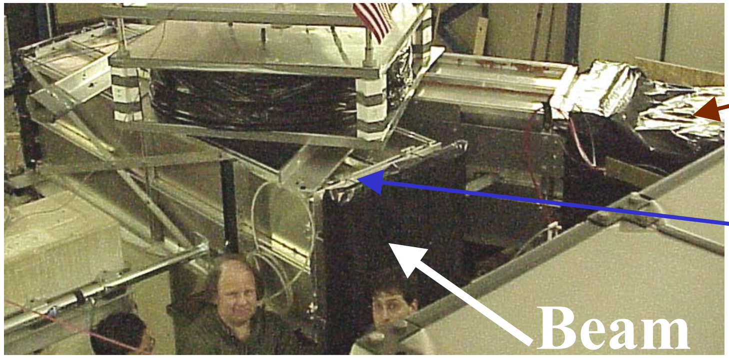
- Silicon Strips *(WBS 1.7):* simple single sided design, mechanics done.

RICH *(WBS 1.3)* : Two Systems

- Gas + Mirror + MAPMT to identify b decay products
- Liquid + PMT's to help with flavor tagging of b's (p/K separation for p < 9 GeV/c)
- Excellent particle id. distinguishes BTeV from "Central pp Detectors"

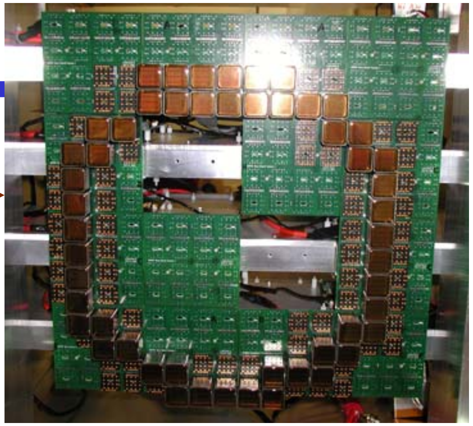


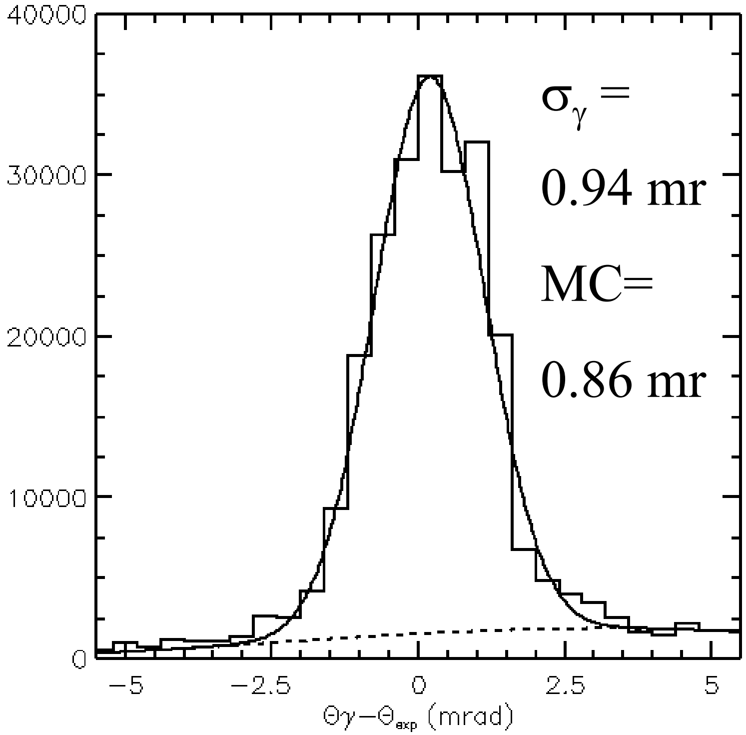
RICH Test Beam

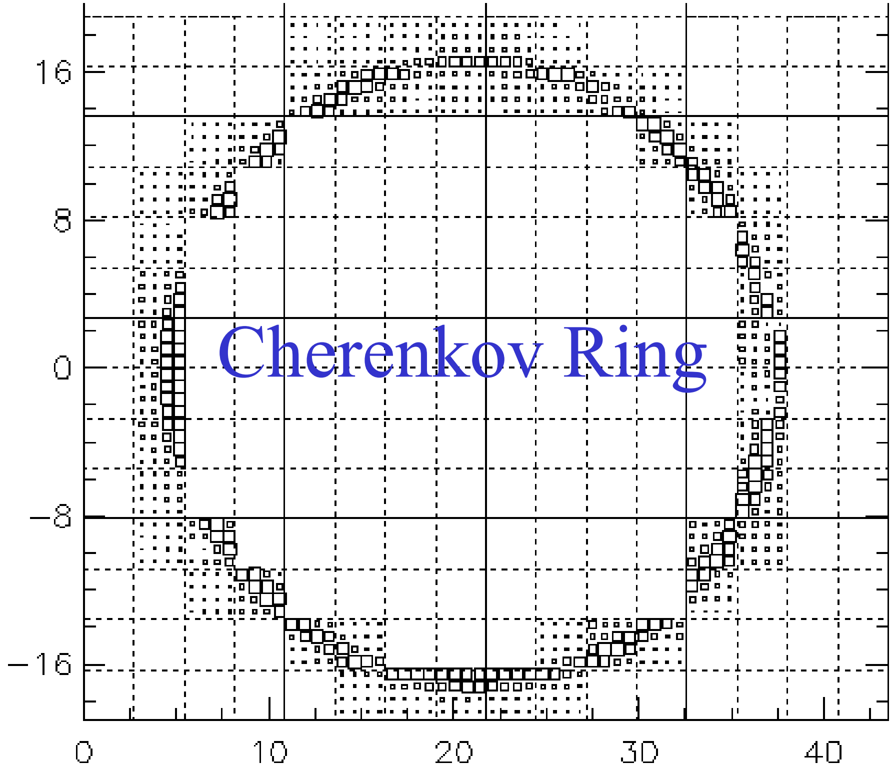


MAPMT array

C_4F_8O radiator



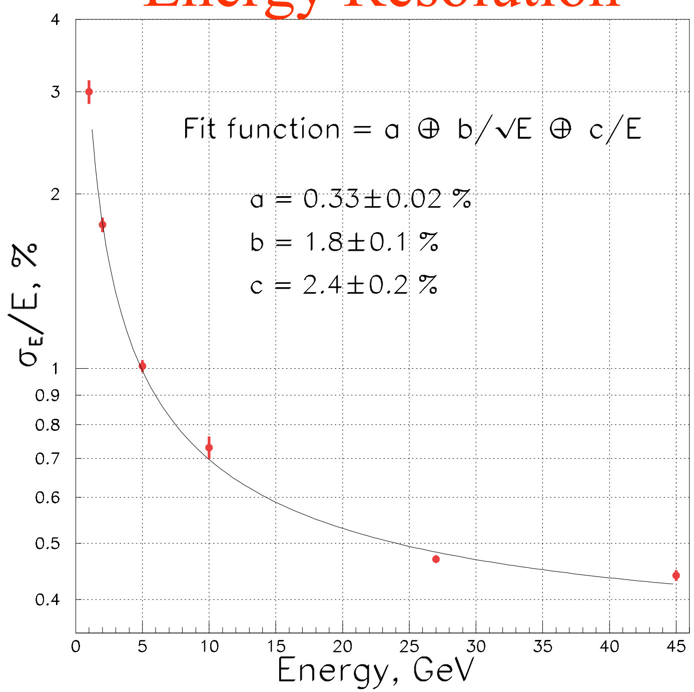




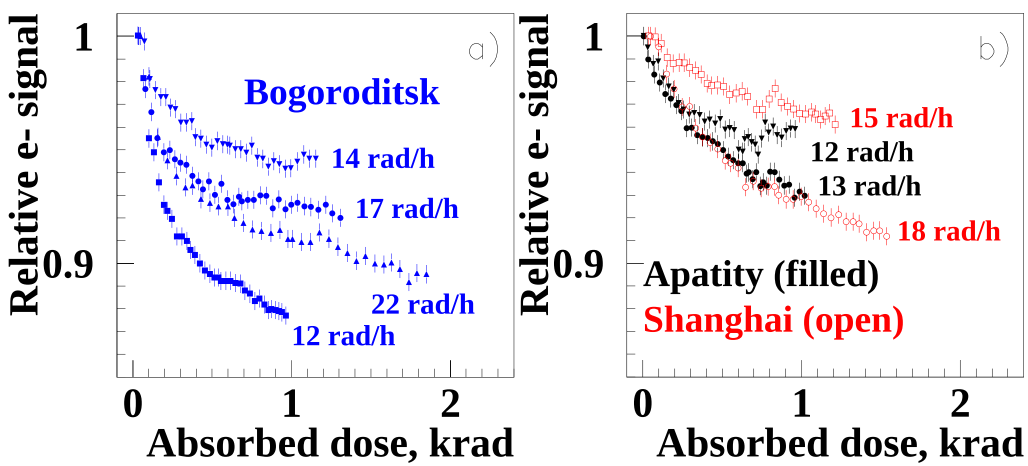
EM cal *(WBS 1.4)* using $PbWO_4$ Crystals

- Use CMS development of crystal technology. Now used for CMS, ALICE, JLAB, etc…
- Use Photomultiplier tubes instead of APD's
- Extensive Test Beam program at Protvino

Energy Resolution



Radiation Damage



Muon System *(WBS 1.5)*

- Used to check detached vertex trigger by having an independent di-muon trigger
- Also used for μ id
- Tested in beams
- Robust design: stainless steel tubes, already tested in beams

Kinds of Requirements

- One set of requirements is based on the physics performance we want the detector to provide
- A second set is internal to the detector subsystem of interest and tells how each individual piece needs to perform (i. e. the efficiencies of PM tubes, or noise on electronics)
- I will concentrate on the first set here, the second set will be covered in the breakouts

Fundamentals

- Luminosity up to 2×10^{32} $cm^{-2}s^{-1}$
- Mean number of interactions per crossing of 6 (thus allowing for 396 ns bunch spacing)
- Radiation Resistance for at least 10 years on all detector components

High Level Requirements

- Charged Tracks
  - Angular acceptance: 10 - 300 mr
  - $p > 3$ GeV/c
  - Tracking efficiency > 98%
  - Mass resolution < 50 MeV/c
  - Primary vertex resolution (along beam) < 100 μm
- Trigger efficiency & rejection
  - $\varepsilon > 50$ % for all B decays with ≥2 charged tracks
  - $\varepsilon > 20$ % for all B decays with 1 charged track
  - Trigger rejection > 98% on light quark events (Level I), and 99.9% at Level III with only a 10% further loss in b efficiency
  - Maximum data rate to archival storage < 200 Mbyte/sec

Hadron & Lepton Identification

- π/K separation $\geq 4\sigma$ for momenta 3 - 70 GeV/c
- p/K separation $\geq 3\sigma$ for momenta 3 - 70 GeV/c
  - These allow for π/e & π/μ separation at 4σ level up to ~23 and ~17 GeV/c, respectively
- positive μ identification from 5 - 100 GeV/c with a fake rate $< 10^{-3}$ and an independent momentum determination with resolution

$$\frac{\sigma_p}{p} = 19\% \oplus 0.6\% \times p$$

Electromagnetic Calorimeter *(WBS 1.4)*

- Radius up to 160 cm ~220 mr, with hole for beam ~10 mr
- Range E > 1 GeV
- Energy resolution

$$\frac{\sigma_E}{E} < \frac{2\%}{\sqrt{E}} \oplus 1\%$$

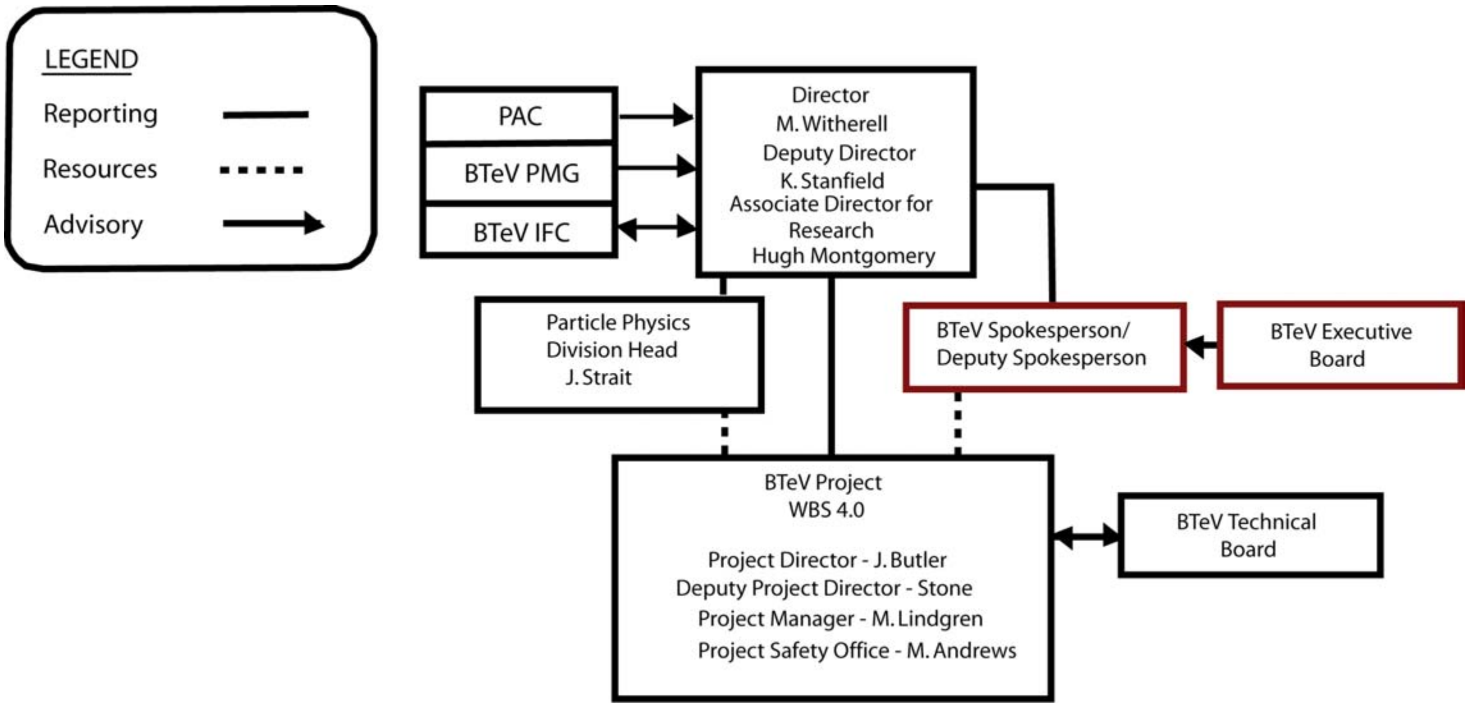
- Position resolution

$$\sigma_x < \frac{4\ \mathrm{mm}}{\sqrt{E}} \oplus 1\,\mathrm{mm}$$

Matrix of Responsibility for Subprojects

Magnets, Toroids, Beampipes *(WBS 1.1)*	**FNAL**
Pixels *(WBS 1.2)*	Iowa, **FNAL**, Wayne State, Syracuse, Tennessee, Frascati,, Milano
RICH *(WBS 1.3)*	**Syracuse**, FNAL
EMCAL *(WBS 1.4)*	Belarus, IHEP Protvino, **Minnesota**, Nanjing, University of Science and Technology, Shandong U, York
Muons *(WBS 1.5)*	**Vanderbilt**, Puerto Rico, Ilinois
Forward Straw Tracker *(WBS 1.6)*	**FNAL**, Virginia, SMU, Houston, Frascati, Davis
Forward Microstrips *(WBS 1.7)*	**Milano**, Colorado, Pavia, Insubria, FNAL
Trigger *(WBS 1.8)*	**FNAL**, Ilinois, IIT, NMSU
DAQ *(WBS 1.9)*	**FNAL**, Ohio State
Integration *(WBS 1.10)*	**FNAL**

Relationship of Collaboration & Project



- Collaboration provides manpower for Project and for Software, pre-operations, etc…monthly meetings
- MOU's signed between Universities, Foreign labs (Protvino, INFN) with Fermilab, for duration of Project; SOW's signed yearly
- Technical Board meetings weekly (All Level 1 & Level 2 managers attend)
- PMG: Fermilab management, division heads, BTeV Project; meets monthly

MOU Status

	Circulating within subproject	Under Review				Signed
		Project Office	Colla-boration	Univ OSP	FNAL mangmnt	
Vanderbilt	x	x	x	x	x	X
Syracuse	x	x	x	x	x	X
Minnesota	x	x	x	x		
U of Illinois	x					
Puerto Rico	x					
Wayne State	x					
Virginia	x					

Endorsements & Request

- BTeV was included as a near term priority in the category of "Highest Scientific Importance and Near-term Readiness for Construction," in the "Facilities for the Future of Science: A Twenty-year Outlook" report of the Office of Science
- P5 originally wrote: "P5 supports the construction of BTeV as an important project in the world-wide quark flavor physics area."
- From the recent P5 report: "Given our analysis, we find that our conclusions of last year are unchanged in the staging scenario proposed by BTeV and we reaffirm these conclusions. The method of staging chosen by BTeV is an appropriate choice to maximize their physics opportunities"
- *BTeV requests that you recommend DOE approval for CD-2/3a allowing for limited construction in FY2005 in order that we can remain on schedule and become a highly successful DOE high energy physics project*

Schedule Considerations

- We are assuming receipt of CD-2/3a allowing us to spend construction funds on April 1, 2005
- Previous DOE CD-1 review committee recommended approval for our Staged Schedule
- The completion date for most project elements is Aug. 1, 2009, the project completion date is Sept. 30, 2004
- Rationale for Staging
  - By the end of 2009 we will be able to run as early as possible with full sensitivity for decays to all charged final states and about 60% of the ultimate sensitivity for states with photons
  - In 2010, we will complete our γ capability and quickly overtake our competition to be the best B physics experiment world wide.

Summary

- BTeV has
  - World class physics
  - State of the art, best of breed, detector design
  - Strong & Cohesive collaboration
  - Strong management team & strong commitment from Fermilab
- BTeV is READY TO GO:
  - *BTeV, however, needs CD-2/3a allowing for limited construction in FY2005 to remain on schedule and do great physics*

Rest of Plenary Talks

- Project Director, Joel Butler:
  Project Definition and FY05 plans
- Project Manager, Mike Lindgren:
  Project Cost, Schedule and Management

The End